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Assessment

Ethics approval and consent to participate: The medical ethics committee of the VUmc assessed the present study, and decided the Dutch Medical Research Involving Human Subjects Act (WMO) was not applicable (registered under number 2013.454). All participants gave informed consent. The trial is registered at the Dutch Trial Register (NTR5474). *Authors' contributions:* S.H.W. has been involved in the development of the TTCM, the design of the study, the implementation of the TTCM, the data collection, the data analysis and writing the manuscript. JMD was closely involved in the design of the study, was responsible for the economic evaluation and involved in writing the manuscript. EG and RJH were substantially involved in development of the TTCM and negotiated a model for reimbursement with hospital managers, policy makers and insurers. F.W.B., V.G., and R.W.O. were involved in the overall design of the study and were critically reading the manuscript for important intellectual content. All authors read and approved the final manuscript. *Acknowledgements:* We thank all trauma patients who participated in the study. Furthermore, we thank Frank Duijff and Sander Assendelft from FysioRoadmap for their ongoing support and technical assistance during the project. Finally we thank Milou Rossenaar for her help with the cost-effectiveness analyses as a part of her graduation thesis. *Financial support:* This project is partly funded by "Zilveren Kruis Health Insurer" (grant number Z516).

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Cost-Effectiveness of the Transmural Trauma Care Model (TTCM) for the Rehabilitation of Trauma Patients

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Abstract

Objectives. To assess the societal cost-effectiveness of the Transmural Trauma Care Model (TTCM), a multidisciplinary transmural rehabilitation model for trauma patients, compared with regular care.

Methods. The economic evaluation was performed alongside a before-and-after study, with a convenience control group measured only afterward, and a 9-month follow-up. Control group patients received regular care and were measured before implementation of the TTCM. Intervention group patients received the TTCM and were measured after its implementation. The primary outcome was generic health-related quality of life (HR-QOL). Secondary outcomes included disease-specific HR-QOL, pain, functional status, and perceived recovery.

Results. Eighty-three trauma patients were included in the intervention group and fifty-seven in the control group. Total societal costs were lower in the intervention group than in the control group, but not statistically significantly so (EUR-267; 95 percent confidence interval [CI], EUR-4,175–3011). At 9 months, there was no statistically significant between-group differences in generic HR-QOL (0.05;95 percent CI, −0.02–0.12) and perceived recovery (0.09;95 percent CI, −0.09–0.28). However, mean between-group differences were statistically significantly in favor of the intervention group for disease-specific HR-QOL (−8.2;95 percent CI, −15.0–−1.4), pain (−0.84;95CI, −1.42–−0.26), and functional status (−20.1;95 percent CI, −29.6–−10.7). Cost-effectiveness acceptability curves indicated that if decision makers are not willing to pay anything per unit of effect gained, the TTCM has a 0.54–0.58 probability of being cost-effective compared with regular care. For all outcomes, this probability increased with increasing values of willingness-to-pay.

Conclusions. The TTCM may be cost-effective compared with regular care, depending on the decision-makers willingness to pay and the probability of cost-effectiveness that they perceive as acceptable.

Traumatic injury is the leading cause of death during the first 4 decades of life, accounts for 9.6 percent of global mortality (1;2), and causes the biggest loss of disability-adjusted life-years compared with any other disease (3). Traumatic injury disproportionately affects younger individuals and, as a consequence, accounts for the highest amount of lost productive years of life (4). While the direct medical costs of traumatic injury are substantial, its economic burden is particularly high for employers. To illustrate, in the United States, the total cost of fatal unintentional injury was estimated at approximately USD84 billion, of which the largest share was due to lost productivity (i.e., approximately USD83 billion) (4). In the Netherlands, the total cost of trauma (intentional and unintentional) was estimated to be EUR6 billion, of which EUR2.6 billion were direct medical costs and EUR3.4 billion were lost productivity costs (5).

During the past 3 decades, an improved organization of acute trauma care has led to a 15 percent to 25 percent decrease in mortality (6–8). As further improvements in survival rates are likely to be relatively small, the focus of trauma care has moved from reducing mortality to improving quality of life and outcome (9). A possible means for improving trauma patients' health-related quality of life (HR-QOL) and outcome may be the optimization of their rehabilitation process. We, therefore, developed the Transmural Trauma Care Model (TTCM), which aims to improve the organization, content, and quality of the trauma patients' rehabilitation process. The TTCM consists of a continuous feedback loop, in which a

multidisciplinary hospital-based team supervises a network of primary care physical therapists in the treatment of trauma patients (10). Effectiveness analyses showed that, among trauma patients with at least one fracture, the TTCM resulted in better patient outcomes, such as disease-specific HR-QOL, pain, and functional status, compared with regular care (Wiertsema et al., unpublished data).

As healthcare resources are restricted, trauma systems should not only be effective in improving patient outcomes, but also provide "good value for money." The latter is assessed in an economic evaluation, which provides insight into a treatment's additional cost per additional unit of health gained (11). Up until now, relatively few economic evaluations evaluated the cost-effectiveness of trauma systems (12–14), and those aimed at the rehabilitation phase in particular. Therefore, the current economic evaluation aimed to assess the cost-effectiveness of the TTCM for generic HR-QOL from a societal perspective compared with regular care. In a secondary analysis, the intervention's cost-effectiveness for disease-specific HR-QOL, pain, functional status, and perceived recovery was assessed.

Methods

The study protocol has been published elsewhere (10). A summary is given below.

Design

The economic evaluation was conducted alongside a before-and-after study with a convenience control group measured only afterward. This clinical trial was conducted at the outpatient clinic of a level-1 trauma center (Amsterdam UMC, location VUmc, Amsterdam, the Netherlands) (15). In contrast to a *true* controlled-before-and-after study, only the intervention group was prospectively followed, while control group data were collected cross-sectionally. That is, the trial's control group consisted of four independent clusters of patients who either had their first consultation at the outpatient clinic 0, 3, 6, or 9 months ago. After implementation of the TTCM, one cluster of intervention group patients was prospectively followed and measured directly after their first consultation at the outpatient clinic (i.e., baseline), and after 3, 6, and 9 months (Figure 1). To capture all costs flowing from the intervention under study, the analytic time frame of an economic evaluation typically needs to be longer than that of an effectiveness study (16). Therefore, in the present economic evaluation, only the 9-month control cluster was compared with the intervention group. The 9-month control cluster will be further referred to as the control group.

The medical ethics committee of the VUmc decided that the Dutch Medical Research Involving Human Subjects Act (WMO) was not applicable to the present study (registered under number 2013.454). All participants gave informed consent. The trial is registered at the Dutch Trial Register (NTR5474).

Participants

Surgically as well as conservatively treated trauma patients were included. Eligible trauma patients had at least one traumatic fracture, were aged ≥18 years, rehabilitated in the primary care setting, and were able to fill out online questionnaires in Dutch. Patients were excluded if they met any of the following criteria: traumatic brain injury, pathological (nontraumatic) fractures, cognitive limitations, rehabilitation in a tertiary care facility, or living outside the catchment area of the VUmc.

Control group patients were identified from the central trauma registry of the trauma region "North West Netherlands" and were contacted by phone by one of the investigators. They received further information about the study, after which the principle investigator verified the in- and exclusion criteria and patients were assigned to their specific cluster (based on the time elapsed since their first consultation). Eligible patients who were willing to participate received an email containing a link to the online questionnaire. Patients who did not respond within one week received a maximum of two reminder emails. If the patient did not reply to both emails, one of the coordinating investigators contacted the patient by phone.

Intervention group patients were identified during their first consultation at the outpatient clinic. During this consultation, patients were informed about the study by one of the investigators and in- and exclusion criteria were verified. In the week following the first consultation, patients who were willing and eligible to participate, received an email containing a link to the first online questionnaire. Subsequently, patients were prospectively followed and received additional online questionnaires at 3-, 6-, and 9-month follow-up. Patients who did not respond within 1 week, received a maximum of two reminder emails. If the patient did not reply to both emails, one of the coordinating investigators contacted the patient by phone.

Intervention Conditions

Pre- and in-hospital trauma care remained unchanged and was the same for the intervention group and the control group.

The TTCM

Patients in the intervention group received care according to the TTCM (10). The TTCM combined the following components:

A multidisciplinary team consisting of a trauma surgeon and a highly-specialized hospital-based trauma physical therapist at the outpatient clinic for trauma patients

The trauma surgeon acted as the chief consultant, the physical therapist assessed physical function and acted as case manager throughout the rehabilitation process. During a shared decision-making process, the surgeon, physical therapist, and patient determined whether and when physical therapy in primary care was required.

Coordination and individual goal setting for each patient by this hospital-based team in combination with treatment according to customized protocols

The hospital-based team coordinated the patients' rehabilitation process by repeatedly defining individual goals with the patient during the rehabilitation period. For the purpose of the TTCM, ten rehabilitation protocols were developed for the most common fractures (e.g., hip fractures, tibial plateau fractures).

A network of forty specialized primary care physical therapists

This so called "VUmc trauma rehabilitation network" consisted of forty physical therapists covering the region of Amsterdam (www.traumarevalidatie.nl) (17). The forty primary care physical therapists participating in the trauma network were trained and

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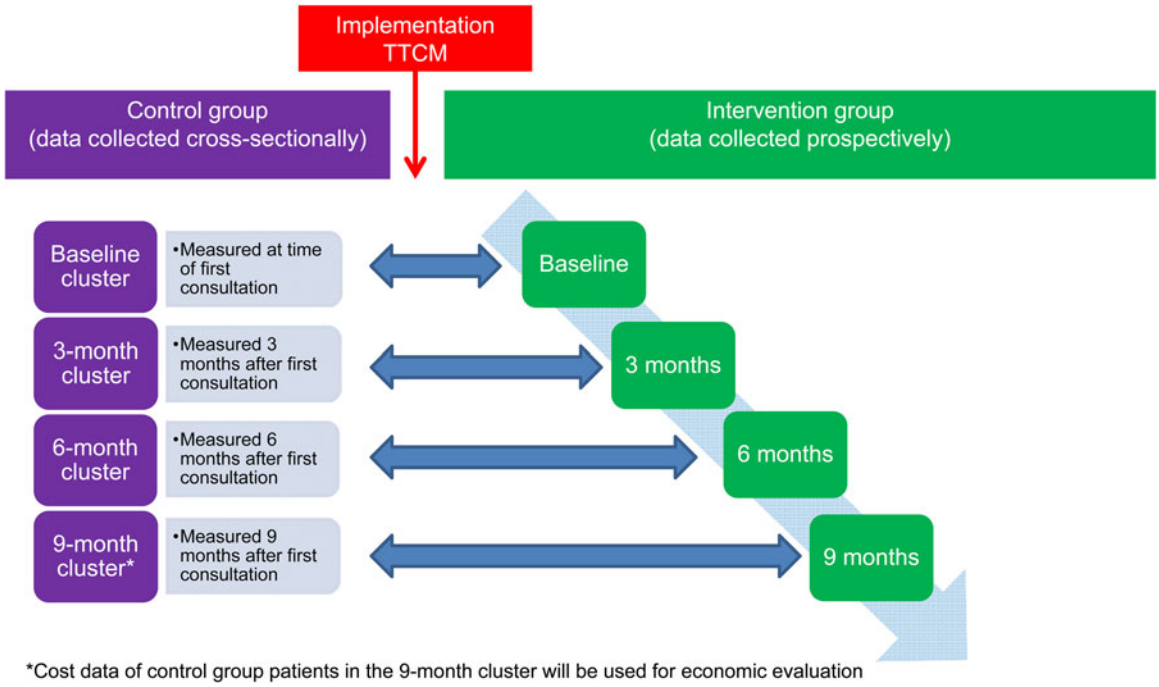

Fig. 1. Study design of the modified controlled before and after study.

educated during a 2-day course led by trauma surgeons and hospital-based physical therapists, specialized in trauma care.

E-health support for transmural communication between the hospital-based trauma physical therapist and the primary care physical therapist

The hospital-based physical therapist and the primary care physical therapist communicated repeatedly throughout the rehabilitation process using secured email (especially developed for healthcare professionals).

Regular Care

Patients in the control group received regular postclinical care during which the trauma surgeon acted as the chief consultant and performed the postclinical consultations, unaccompanied by any allied health care professionals. The trauma surgeon decided whether and when physical therapy in primary care was needed. During a patients' rehabilitation, there was no regular contact between the surgeon and the primary care physical therapist.

Outcome Measures

Various demographic and trauma-related characteristics were assessed for all patients (e.g., age, gender, medical history, Injury Severity Score [ISS], time between trauma and first outpatient consultation [TTO]). These characteristics were collected using online questionnaires, supplemented by data derived from electronic patient records.

The primary outcome was generic HR-QOL. Secondary outcomes included disease-specific HR-QOL, pain, functional status, and perceived recovery. In the intervention group, outcome measures were assessed at 0, 3, 6, and 9 months after patients' first consultation at the outpatient clinic. In the control group, outcome measures were solely assessed at 9 months after the patients' first consultation at the outpatient clinic.

Generic HR-QOL was measured using the EQ-5D-3L (18). Using the Dutch tariff, the participants' EQ-5D-3L health states were converted into a utility score, anchored at 0 (dead) and 1 (optimal health). As control group participants were only measured once, we were not able to estimate quality-adjusted life-years and include them as an outcome measure in the current economic evaluation. Nonetheless, generic HR-QOL can still be regarded as a preference-based measure, as utility values were based on the preferences of the Dutch population.

Disease-specific HR-QOL was measured using four disease-specific function scales, appropriate to the patients' specific injury type. The Quick Dash score was filled out by patients with fractures of the upper extremity (19;20). The Lower Extremity Functional Scale (LEFS) was used in patients with hip fractures or other lower extremity fractures (21;22). The Roland Morris Disability Score (RMDS) was filled out by patients with vertebral fractures (23;24). The Groningen Activity Restriction Scale (GARS) was used in multi trauma patients (25). An overall disease-specific HR-QOL score was calculated by converting the overall scores of the four above-mentioned questionnaires to a scale from 0–100, with higher scores representing more functional problems.

Pain was measured using an 11-point numeric pain rating scale (NPRS), ranging from 0 (no pain) to 10 (worst possible pain) (26).

Functional status was measured using the Patient Specific Function Scale (PSFS) (27;28). Patients had to identify three important activities that they are having difficulty with and were requested to rate their current level of difficulty associated with each activity on an 0–100 mm visual analogue scale (VAS) ranging from 0 ("able to perform activity at same level as before injury or problem") to 100 ("unable to perform activity"). Only the activity that was first mentioned by the patient was used in the economic evaluation.

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Perceived recovery was measured using the Global Perceived Effect (GPE) scale. Patients were asked to rate how much their condition has improved or deteriorated since their trauma on a seven-item scale (29). Success of treatment was achieved when a patient reported to being "completely recovered" or "much improved."

Cost Measures

Costs were measured from a societal perspective, including intervention, health care, absenteeism, presenteeism, and unpaid productivity costs. Intervention costs included all costs related to the additional time investments of the hospital-based trauma physical therapist (estimated at 15 minutes per outpatient clinic consultation) and the specialized primary care physical therapist (estimated at 5 minutes per outpatient clinic consultation), as well as the cost of hosting and maintaining the transmural communication system. The costs associated with the TTCM's development (e.g., training costs) were excluded, as these costs will become negligible after implementing the intervention broadly (30;31). All other cost categories were assessed using online cost questionnaires, supplemented by hospital records if available (e.g., for imaging procedures). To cover the complete duration of follow-up, recall periods of the online questionnaires varied between treatment groups and measurement points. For the intervention group, 3-month recall periods were used at baseline, 3, 6, and 9 months follow-up and costs were added together to get an estimate of the total costs during the 9-month follow-up period. For the control group, a recall period of 9 months was used at 9-month follow-up.

Healthcare use included the use of primary care (e.g., consultations at the general practitioner or physical therapist) and secondary care (e.g., consultations at the outpatient clinic for trauma patients, hospitalization) as well as the use of medication. Dutch standard costs were used to value healthcare costs (31). Medication use was valued using the G-standard of the Dutch Society of Pharmacy (32).

Absenteeism was assessed using the "PROductivity and DISease Questionnaire" (PRODISQ). Patients were asked to report their total number of sick leave days (33). Absenteeism was valued using age- and gender-specific price weights (31).

Presenteeism was defined as reduced productivity while at work and was assessed using the World Health Organization Health and Work Performance Questionnaire (34). Presenteeism was valued using age- and gender-specific price weights (31).

Unpaid productivity losses were assessed by asking patients for how many hours per week they were unable to perform unpaid activities, such as domestic work, school, and voluntary work. A recommended Dutch shadow price was used to value unpaid productivity. The Dutch shadow price was calculated in accordance with the opportunity good method and was estimated to be EUR12.50 per hour in 2009 (31).

All costs were presented in Euros and converted to the same reference year (i.e., 2014) using consumer price indices. Discounting of costs was not necessary due to the 9-month follow-up period (11).

Data Analysis

Descriptive Statistics

Descriptive statistics were used to compare baseline characteristics between intervention and control group participants.

Handling Missing Data

Missing data were imputed using Multiple Imputation by Chained Equations (35). Two imputation models were constructed, including one for the intervention group and one for the control group. Both imputation models included variables related to the "missingness" of data, variables that predicted the outcomes, and all available midpoint and follow-up cost and effect measure values (35). Ten complete data sets were created in order for the loss-of-efficiency to be below 5 percent (36). Imputed datasets were analysed separately as specified below, after which pooled estimates were calculated using Rubin's rules (36).

Economic Evaluation

Cost-effectiveness analyses were performed according to the intention-to-treat principle. Cost and effect differences were estimated using seemingly unrelated regression analyses to correct for their possible correlation. Cost and effect differences were corrected for confounders. Confounding was checked by adding the potential confounding variable to the crude models, and was subsequently considered to be present if the regression coefficient changed by 10 percent or more. To deal with the highly skewed nature of cost data, 95 percent confidence intervals around the differences in costs were estimated using the bias corrected and accelerated bootstrap method, with 5,000 replications. Incremental cost-effectiveness ratios (ICERs) were calculated by dividing the differences in costs by those in effects. To graphically illustrate the uncertainty surrounding the ICERs, bootstrapped incremental cost-effect pairs were plotted on cost-effectiveness planes (37).

A summary measure of the joint uncertainty of costs and effects was presented using cost-effectiveness acceptability curves (CEACs), which indicate the probability of an intervention being cost-effective in comparison with the control condition for a range of willingness-to-pay values (i.e., the maximum amount of money decision makers are willing to pay to gain one extra unit of effect) (38). Two one-way structural sensitivity analyses were performed to test the robustness of the results: (i) applying the healthcare perspective (i.e., only costs accruing to the Dutch healthcare system were included), and (ii) excluding presenteeism costs (11). All analyses were performed in STATA, using a level of significance of $p < .05$.

Results

Study Participants

Eighty-three trauma patients were enrolled in the intervention group and 57 in the control group (Supplementary Figure 1). Most baseline characteristics were similar among intervention and control group patients. However, patients in the intervention group were slightly younger, were more frequently admitted to a hospital, received surgery more frequently, and had a longer time between trauma and their first outpatient consultation than their control group counterparts (Table 1). A total of 107 patients (76 percent) had complete effect data at 9 months follow-up (i.e., 52 intervention group patients and 55 control group patients) and 62 patients (44 percent) had complete cost data on all measurement points (i.e., seventeen intervention group patients and forty-five control group patients).

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Table 1. Baseline Characteristics (Patient- and Trauma Related)

Characteristics	Intervention group Mean (SD) *or* frequency (%)	Control group Mean (SD) *or* frequency (%)
N	83	57
Age	43.4 (15.6)	50.5 (17.9)
Gender (M/F)	39/44 (47/53%)	26/31 (46/54%)
Education level		
Low	7 (8.4%)	6 (11.1%)
Middle	19 (22.9%)	16 (29.6%)
High	57 (68.7%)	32 (59.3%)
Medical history		
None	53 (63.9%)	30 (52.6%)
Chronic	14 (16.9%)	13 (22.8%)
Musculoskeletal	16 (19.3%)	14 (24.6%)
Trauma type		
Traffic	44 (53.0%)	25 (43.9%)
Work related	0	2 (3.5%)
Fall	27 (32.5%)	17 (29.8%)
Sports	11 (13.3%)	9 (15.8%)
Other	1 (1.2%)	4 (7.0%)
Fracture region		
Upper extremity	31 (37.3%)	25 (43.9%)
Lower extremity	41 (49.4%)	19 (33.0%)
Vertebral	7 (8.4%)	1 (1.8%)
Multitrauma	4 (4.8%)	12 (21.1%)
ISS	7.9 (range 4-26, SD 4.4)	8.6 (range 4-29, SD 6.3)
Admission hospital	62 (75%)	29 (51%)
Length of stay	7.1 (6.1)	10.0 (11.4)
Surgery	53 (64%)	21 (37%)
TTO (days)	24.3 (14.3)	14.6 (14.7)

M/F, male/female; SD, standard deviation; TTO, time between trauma and first outpatient consultation.

Effectiveness

At 9 months, there was no statistically significant difference in the primary outcome generic HR-QOL between the intervention group and control group. As for the secondary outcomes, mean between-group differences were statistically significantly in favor of the intervention group for disease-specific HR-QOL, pain, and functional status, but not for perceived recovery (Table 2).

Costs

On average, the cost of the TTCM was EUR272 (SEM = EUR4) per patient. Secondary healthcare, presenteeism, and total societal costs were lower in the intervention group than in the control group, while primary healthcare, medication, absenteeism, and unpaid productivity costs were higher in the intervention group than in the control group. Of them, only the difference in secondary healthcare costs was statistically significant (Table 3).

Economic Evaluation

Primary Outcome. Generic HR-QOL

The main analysis results for generic HR-QOL indicated that the TTCM dominated regular care (i.e., less costly and more effective) (Table 2). The CEAC in Supplementary Figure 2 indicates that the TTCM has a 0.58 probability of being cost-effective compared with usual care if decision makers are not willing to pay anything per utility gained, increasing to a maximum of 0.90 at a willingness-to-pay of EUR55,000/utility gained.

Secondary Outcomes. Disease-Specific HR-QOL, Pain, Perceived Recovery, and Functional Status

The main analysis results for disease-specific HR-QOL indicated that the TTCM dominated regular care (i.e., less costly and more effective) (Table 2). Please note that a lower score in disease-specific HR-QOL indicates an improvement. The CEAC in Supplementary Figure 2 indicates that the TTCM has a 0.55 probability of being cost-effective compared with regular care if

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Table 2. Differences in Pooled Mean Costs and Effects (95% CI), ICERs, and the Distribution of Incremental Cost-Effect Pairs around the Quadrants of the CE Planes

	Sample size			ΔC (95% CI)[a]	ΔE (95% CI)[b]	ICER	Distribution CE-plane (%)			
Analysis	Intervention group	Control group	Outcome	EUR	Points	EUR/point	NE[c]	SE[d]	SW[e]	NW[f]
Main analysis	83	57	Generic HR-QOL (0-1)	−237 (−4286 to 3285)	0.05 (−0.02 to 0.12)	−4453	40.7	53.4	2.2	3.7
Imputed dataset	83	57	Disease-specific HR-QOL (0-100)	−232 (−4342 to 3167)	−8.2 (−15.0 to −1.4)	28	39.6	53.5	2.0	5.0
	83	57	Pain (0-10)	−190 (−4140 to 3284)	−0.84 (−1.42 to −0.26)	225	45.1	54.7	0.0	0.1
	83	57	Perceived recovery (0-1)	−192 (−4348 to 3112)	0.09 (−0.09 to 0.28)	2087	36.9	48.2	0.9	0.6
	83	57	Functional status (0-100)	−345 (−4372 to 3121)	−20.1 (−29.6 to −10.7)	17	42.7	57.3	0.0	0.0
One-way	83	57	Generic HR-QOL (0-1)	−491 (−2700 to 393)	0.05 (−0.02 to 0.12)	19	24.3	69.5	0.4	0.2
sensitivity analysis 1	83	57	Disease-specific HR-QOL (0-100)	−466 (−2698 to 317)	−8.2 (−15.0 to −1.4)	57	21.0	68.1	5.1	5.9
Healthcare perspective	83	57	Pain (0-10)	−490 (−2780 to 391)	−0.84 (−1.44 to −0.25)	580	26.4	73.5	0.1	0.0
	83	57	Perceived recovery (0-1)	−454 (−2570 to 412)	0.09 (−0.08 to 0.25)	5725	20.1	62.8	10.4	6.7
	83	57	Functional status (0-100)	−511 (−2749 to 391)	−20.1 (−29.6 to −10.7)	25	24.5	74.5	0.0	0.0
One-way	83	57	Generic HR-QOL (0-1)	339 (−4237 to 4216)	0.05 (−0.02 to 0.12)	6371	52.0	42.1	1.7	4.2
sensitivity analysis 2	83	57	Disease-specific HR-QOL (0-100)	351 (−4222 to 4152)	−8.2 (−15.0 to −1.4)	−43	50.6	41.6	2.0	5.7
Excluding presenteeism	83	57	Pain (0-10)	373 (−4142 to 4179)	−0.84 (−1.44 to −0.25)	−441	56.9	42.9	0.0	0.1
	83	57	Perceived recovery (0-1)	393 (−4327 to 4283)	0.09 (−0.08 to 0.25)	4328	48.9	36.4	6.2	8.5
	83	57	Functional status (0-100)	224 (−4340 to 4045)	−20.1 (−29.6 to −10.7)	−11	54.7	45.3	0.0	0.0

CE, cost-effectiveness; CI, confidence interval; EUR, Euro; HR-QOL, health-related quality of life; ICER, incremental cost-effectiveness ratio; TTO, time between trauma and first outpatient consultation.

Note. Please note that the mean cost differences differ across outcomes. This is due to the use of Seemingly Unrelated Regression analyses, in which cost and effect differences are corrected from their possible correlation.

[a]Cost differences were corrected for medical history, surgery, paid work (yes/no), and number of working hours/week.

[b]Effect differences were corrected for age, medical history, TTO (Generic HR-QOL); age, medical history, TTO, fracture region, admission hospital, surgery (Disease-specific HR-QOL); none (Pain); medical history, TTO (Perceived recovery) and TTO, surgery (Functional status).

[c]Refers to the northeast quadrant of the CE-plane, indicating that the intervention is more effective and more costly than usual care.

[d]Refers to the southeast quadrant of the CE-plane, indicating that the intervention is more effective and less costly than usual care.

[e]Refers to the southwest quadrant of the CE-plane, indicating that the intervention is less effective and less costly than usual care.

[f]Refers to the northwest quadrant of the CE-plane, indicating that the intervention is less effective and more costly than usual care.

Table 3. Mean Costs per Participant inI and Control Groups and Mean Cost Differences between Groups during the 9-Month Follow-up Period

Cost category	Intervention group n = 83; mean (SEM) EUR	Control group n = 57; mean (SEM) EUR	Mean cost difference Unadjusted (95%CI) EUR	Mean cost difference Adjusted (95%CI) EUR
Intervention	272 (4)	0 (0)	272 (257 to 278)	270 (264 to 277)
Healthcare	2,397 (174)	3,003 (639)	−606 (−2821 to 218)	−953 (−3854 to 168)
Primary health care	1,138 (108)	925 (152)	212 (−175 to 559)	56 (−440 to 494)
Secondary health care	1,216 (112)	2,005 (567)	−789 (−2853 to -119)	−1,010 (−3696 to -67)
Medication	44 (14)	74 (21)	−29 (−90 to 14)	1 (−65 to 87)
Absenteeism	7,052 (1253)	3,419 (1149)	3,633 (503 to 6292)	595 (−3072 to 3564)
Presenteeism	2,692 (559)	2,274 (533)	418 (−937 to 1679)	−565 (−1769 to 666)
Unpaid productivity	1,408 (250)	1,214 (273)	194 (−483 to 880)	283 (−645 to 1305)
Total	13,822 (1261)	9,910 (1475)	3912 (−457 to 6860)	−267 (−4175 to 3011)

CI, confidence interval; EUR, Euro; SEM, standard error of the mean.

decision makers are not willing to pay anything per one-point improvement in disease-specific HR-QOL, increasing to 0.95 at a willingness-to-pay of EUR700/point improvement.

The main analysis results for pain indicated that the TTCM dominated regular care (i.e., less costly and more effective) (Table 2). Please note that a lower pain score indicates an improvement. The CEAC in Supplementary Figure 2 indicates that the TTCM has a 0.54 probability of being cost-effective compared with regular care if decision makers are not willing to pay anything per one-point improvement in pain, increasing to 0.95 at a willingness-to-pay of EUR3500/point improvement.

The main analysis results for perceived recovery indicated that the TTCM dominated regular care (i.e., less costly and more effective) (Table 2). The CEAC in Supplementary Figure 2 indicates that the TTCM has a 0.54 probability of being cost-effective compared with regular care if decision makers are not willing to pay anything per recovered patient, increasing to a maximum of 0.85 at a willingness-to-pay of EUR50,000/recovered patient.

The main analysis results for functional status indicated that the TTCM dominated regular care (i.e., less costly and more effective) (Table 2). Please note that a lower score in functional status indicates an improvement The CEAC in Supplementary Figure 2 indicates that the TTCM has a 0.57 probability of being cost-effective compared with regular care if decision makers are not willing to pay anything per point improvement in functional status, increasing to 0.95 at a willingness-to-pay of EUR125/point improvement.

One-Way Sensitivity Analyses

When the healthcare perspective was applied, the mean difference in total costs was larger than in the main analysis (e.g., EUR-491 versus EUR-237 for general HR-QOL), and still in favor of the intervention group. This resulted in higher probabilities of the TTCM being cost-effective compared with the main analysis (Table 2). When excluding presenteeism costs, total costs were higher in the intervention group than in the control group. This finding was in contrast to the main analysis, and resulted in lower probabilities of the TTCM being cost-effective (Table 2).

Discussion

Traumatic injury is the most important cause of long-term functional limitations in adults younger than 45 years (39) and poses a substantial economic burden to society (40). As healthcare resources are restricted, trauma systems should not only be effective in improving patient outcomes, but also provide "good value for money". Therefore, the current economic evaluation aimed to assess the cost-effectiveness of the TTCM for generic HR-QOL from a societal perspective compared with regular care. In a secondary analysis, the intervention's cost-effectiveness for disease-specific HR-QOL, pain, functional status, and perceived recovery was assessed.

Main Findings

Results indicated that the TTCM statistically significantly improved disease-specific HR-QOL, pain, and functional status compared with regular care. Between-group differences in generic HR-QOL, perceived recovery, and total costs were in favor of the intervention group as well, but not statistically significantly so. On average, the TTCM dominated regular care for all outcomes. CEACs indicated that if decision makers are not willing to pay anything per unit of effect gained, the TTCM has a 0.54–0.58 probability of being cost-effective compared with usual practice. For all outcomes, this probability increased to relatively high levels with increasing values of willingness-to-pay (e.g., to 0.95 at a willingness-to-pay of EUR700/point improvement on a NRS). However, as it is unknown what decision makers are currently willing-to-pay per unit of effect gained, strong conclusions cannot be made about the cost-effectiveness of the TTCM. Nonetheless, decision makers need to understand the role that rehabilitation, job retraining, and injury prevention play in dealing with the tremendous economic impact of traumatic injury to society and they can use the present results to consider whether the TTCM provides "good value for money" at an acceptable probability of cost-effectiveness.

Comparison with the Literature

Even though extensive research has been done on the quality and organization of pre- and in-hospital trauma care, relatively few economic evaluations have evaluated the cost-effectiveness of regionalized trauma systems (12–14), and those aimed at the rehabilitation phase in particular. A recent study assessed the cost-effectiveness of several care pathways for inpatient rehabilitation in severe trauma patients (41). All participants were treated

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in a specialized trauma hospital, but the group that rehabilitated in an in-hospital rehabilitation center, had a significantly shorter length of stay (LOS) compared with the group that rehabilitated in an external rehabilitation center. However, this was a retrospective cohort study that solely used LOS as a proxy for resource consumption and, therefore, cannot be considered as a full economic evaluation. Furthermore, a Dutch study evaluated an integrated inpatient "Fast Track" rehabilitation service for multi trauma patients.

No significant effect differences were observed between the intervention and control group and results of the scheduled economic evaluation have not yet been published (42). Another study evaluated the cost-effectiveness of three inpatient rehabilitation modalities (i.e., physically orientated, geriatrically orientated, and routine treatment) in patients with hip fractures. Considering total costs 1 year after trauma, physically orientated rehabilitation showed to be more cost-effective than routine treatment. Although it was a robust study, the results were not generalizable to other trauma patients (43). To the best of our knowledge, the present study is the first to evaluate the cost-effectiveness of a transmural care model for the postclinical rehabilitation of trauma patients.

Strengths and Weaknesses of the Study

Important strengths of this study are the fact that it was the first to evaluate the cost-effectiveness of a new multidisciplinary transmural rehabilitation model for trauma patients, its use of a control group and its pragmatic design (i.e., daily practice is resembled as much as possible). Also, the study population covers a broad range in trauma patients (ISS ranging from 4 to 43). This is an important strength, as the majority of studies assessing HR-QOL, functional outcomes and costs after trauma, included only major trauma patients with an ISS > 16 (39;44;45) or trauma patients with specific injuries (e.g., hip fractures or vertebral fractures) (46). As our study population represents the whole spectrum from mild to severely injured trauma patients, the results are likely to be generalizable to the total trauma patient population (except patients with traumatic brain injury, which were excluded in this study). However, future research is necessary to explore whether specific trauma patient subgroups respond in a different way on the TTCM.

The study also had some limitations. First, a controlled-before-and-after design, with a convenience control group measured only afterward, was regarded as the most optimal research design within the available resources and within the possibilities of clinical practice. However, such nonrandomized study designs are inherently susceptible to many types of bias, such as selection bias, recall bias, regression to the mean, the Hawthorne effect, and repeat testing bias (47). Most likely in the present study is the occurrence of selection bias, meaning that the control group and intervention group are likely to differ in known and unknown etiological factors. As a consequence, it is not possible to rule out the possibility that the current findings are biased by baseline differences in group characteristics, and those that we were not able to measure due to the current study design in particular (15). Even though we were able to correct for some of them in our analyses, a randomized controlled design or an observational design with a propensity score matched control group would have likely produced more valid results. Among others, this is evidenced by the fact that after correcting the total cost difference for medical history, surgery, paid work, and working hours it changed from being positive to negative, albeit not statistically significant in both cases.

Another potential form of bias is the possible influence of recall bias due to the use of retrospective questionnaires with varying recall periods. The assumption is that a longer recall period increases the change of recall bias due to difficulties in recollecting facts and events after an elongated period of time. As control group patients were asked to remember their resource use during the last 9 months instead of during the past 3 months (which was the case for the intervention group), one might argue that the costs of the control group have a higher probability of being *underestimated* than those of the intervention group. However, as total societal costs were higher in the control group than in the intervention group, it seems unlikely that the use of retrospective questionnaires severely biased our results.

A second shortcoming of the present study was the inability to include quality-adjusted life-years in the current economic evaluation, because utilities of the control group were only measured at one single time point.

A third shortcoming is the relatively short time horizon of the clinical trial. Short time horizons are common in trial-based economic evaluations, as longer follow-ups are typically not feasible within a trial setting. One should bear in mind, however, that an intervention's cost-effectiveness observed within a trial may be substantially different from its longer-term cost-effectiveness. To deal with this limitation, the intervention's longer-term cost-effectiveness can be estimated using modelling techniques (48).

Finally, and inherent to all economic evaluations, is the fact that the current results may not be generalizable to other countries due to differences in healthcare systems across countries. Also, despite extensive efforts to limit the amount of missing data, 56 percent of all participants had some missing cost data and 24 percent had some missing effect data. Although missing data are generally unavoidable in clinical studies and economic evaluations in particular, and multiple imputation techniques were used for filling in missing values, a complete dataset would have produced more valid and reliable results.

Implications for Practice and Further Research

Decision makers can use the present results to consider whether the TTCM provides "good value for money" at an acceptable probability of cost-effectiveness. Implementation of the TTCM in other level-1 trauma centers could be considered in the future, although a multicenter controlled trial would be required to confirm the present results.

In conclusion, the TTCM may be cost-effective compared with regular care, depending on the decision-makers willingness to pay and the probability of cost-effectiveness that they perceive as acceptable. However, a multicenter, and ideally randomized controlled trial, would be preferred to fortify the results of this pragmatic study.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0266462319000436

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